

## **Configuring solid-state batteries to power electric vehicles: A technology and energy deliberation**

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Table S1. The Roadmap of Energy-saving and New Energy Vehicle Technology, issued in 2016.

| 2020   | 2025   | 2030  |
|--|--|---|
| <p><b>g-ED:</b> 350 Wh kg<sup>-1</sup> (cell),<br/>250 Wh kg<sup>-1</sup> (system);</p> <p><b>v-ED:</b> 650 Wh kg<sup>-1</sup> (cell),<br/>320 Wh kg<sup>-1</sup> (system);</p> <p><b>PD:</b> 1000 W kg<sup>-1</sup> (cell),<br/>700 W kg<sup>-1</sup> (system);</p> <p><b>Lifetime:</b> 4000 cycle (10 year)<sup>-1</sup> (cell),<br/>3000 cycle 10 year<sup>-1</sup> (system);</p> <p><b>Cost:</b> 0.6 Yuan Wh<sup>-1</sup> (cell),<br/>1.0 Yuan Wh<sup>-1</sup> (system).</p> | <p><b>g-ED:</b> 400 Wh kg<sup>-1</sup> (cell),<br/>280 Wh kg<sup>-1</sup> (system);</p> <p><b>v-ED:</b> 800 Wh L<sup>-1</sup> (cell),<br/>500 Wh L<sup>-1</sup> (system);</p> <p><b>PD:</b> 1000 W kg<sup>-1</sup> (cell),<br/>700 W kg<sup>-1</sup> (system);</p> <p><b>Lifetime:</b> 4500 cycle (12 year)<sup>-1</sup> (cell),<br/>3500 cycle (12 year)<sup>-1</sup> (system);</p> <p><b>Cost:</b> 0.5 Yuan Wh<sup>-1</sup> (cell),<br/>0.9 Yuan Wh<sup>-1</sup> (system).</p> | <p><b>g-ED:</b> 500 Wh kg<sup>-1</sup> (cell),<br/>350 Wh kg<sup>-1</sup> (system);</p> <p><b>v-ED:</b> 1000 Wh L<sup>-1</sup> (cell),<br/>700 Wh L<sup>-1</sup> (system);</p> <p><b>PD:</b> 1000 W kg<sup>-1</sup> (cell),<br/>700 W kg<sup>-1</sup> (system);</p> <p><b>Lifetime:</b> 5000 cycle (15 year)<sup>-1</sup> (cell),<br/>4000 cycle (15 year)<sup>-1</sup> (system);</p> <p><b>Cost:</b> 0.4 Yuan Wh<sup>-1</sup> (cell),<br/>0.8 Yuan Wh<sup>-1</sup> (system).</p> |

Notes: The Roadmap issued in 2016 sets the battery goals of both cell and system levels. Gravimetric energy density and volumetric energy density are abbreviated as g-ED and v-ED, respectively.

Table S2. The Roadmap of Energy-saving and New Energy Vehicle Technology, 2.0 version, issued in 2020.

|                 |                       | 2020   |   |   | 2025  |  |  | 2030 |  |  |
|-----------------|-----------------------|--|---|---|---|--|--|------|--|--|
| Overall targets | Energy-dense          | Low level  | <b>g-ED:</b> > 200 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 3000 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.35 < Yuan Wh <sup>-1</sup> .                                  | <b>g-ED:</b> > 250 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 3000 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.32 < Yuan Wh <sup>-1</sup> .                                  | <b>g-ED:</b> > 300 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 3000 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.30 < Yuan Wh <sup>-1</sup> .                                  |  |  |      |  |  |
|                 |                       | Middle level   | <b>g-ED:</b> > 200 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 6000 cycle (8 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.45 < Yuan Wh <sup>-1</sup> .                                   | <b>g-ED:</b> > 225 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 6000 cycle (8 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.40 < Yuan Wh <sup>-1</sup> .                                   | <b>g-ED:</b> > 250 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 6000 cycle (8 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.35 < Yuan Wh <sup>-1</sup> .                                   |  |  |      |  |  |
|                 |                       | High level   | <b>g-ED:</b> > 350 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 1500 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.50 < Yuan Wh <sup>-1</sup> .                                  | <b>g-ED:</b> > 400 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 1500 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.45 < Yuan Wh <sup>-1</sup> .                                  | <b>g-ED:</b> > 500 Wh kg <sup>-1</sup> (cell);<br><b>Lifetime:</b> > 1500 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.40 < Yuan Wh <sup>-1</sup> .                            |  |  |      |  |  |
|                 | Energy- & power-dense | M-charge   | <b>g-ED:</b> > 250 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 5000 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.60 < Yuan Wh <sup>-1</sup> .                                  | <b>g-ED:</b> > 300 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 5000 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.55 < Yuan Wh <sup>-1</sup> .                                  | <b>g-ED:</b> > 325 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 5000 cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.50 < Yuan Wh <sup>-1</sup> .                                  |  |  |      |  |  |
|                 |                       | F-charge   | <b>g-ED:</b> > 225 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 3000 cycle (10 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.70 < Yuan Wh <sup>-1</sup> ;<br><b>Charge time:</b> < 15 min. | <b>g-ED:</b> > 250 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 3000 cycle (10 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.65 < Yuan Wh <sup>-1</sup> ;<br><b>Charge time:</b> < 12 min. | <b>g-ED:</b> > 275 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 3000 cycle (10 year) <sup>-1</sup> ;<br><b>Cost:</b> 0.60 < Yuan Wh <sup>-1</sup> ;<br><b>Charge time:</b> < 10 min. |  |  |      |  |  |
|                 | Power-dense           | <b>g-ED:</b> > 80 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 300 k cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> < 1.20 Yuan Wh <sup>-1</sup> . | <b>g-ED:</b> > 100 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 300 k cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> < 1.00 Yuan Wh <sup>-1</sup> .                                 | <b>g-ED:</b> > 120 Wh kg <sup>-1</sup> ;<br><b>Lifetime:</b> > 300 k cycle (12 year) <sup>-1</sup> ;<br><b>Cost:</b> < 0.80 Yuan Wh <sup>-1</sup> .                                 |   |  |  |      |  |  |

Table S3. Densities of cell components.

| Speciation  | Density (g cm <sup>-3</sup> ) |
|---|-------------------------------|
| NCM523  | 4.75                          |
| NCM811  | 4.75                          |
| LM-NCM  | 3.70                          |
| S   | 2.07                          |
| Graphite  | 2.20                          |
| Li  | 0.53                          |
| Carbon (Super P)  | 2.26                          |
| Binder/SBR  | 1.04                          |
| Binder/CMC  | 1.05                          |
| Binder/PVDF   | 1.78                          |
| Binder/NBR  | 1.00                          |
| 1 M LiPF <sub>6</sub> in EC/DEC (for liquid NCM523  Gr) | 1.20                          |
| Sulfidic solid electrolyte (for SSBs)                   | 2.0                           |
| Cu foil   | 8.96                          |
| Al  | 2.70                          |
| Al-plastic film (150 μm)                                | 1.30                          |
| Separator   | 0.946                         |

Notes: Styrene Butadiene Rubber (SBR), Carboxymethyl Cellulose (CMC), Poly(vinylidene fluoride) (PVDF), Nitrile Butadiene Rubber (NBR),

Table S4. Cell parameters assumed in the analysis of ED of liquid NCM523||Gr.

| Speciation                             | Values                       |
|--|------------------------------|
| NCM523 capacity (mAh g <sup>-1</sup> ) | 170.0                        |
| NCM523 potential (V vs. Li)            | 3.7                          |
| Cathode thickness (μm)                 | 100.0                        |
| Cathode porosity (vol.%)               | 30.0                         |
| Active material in cathode (vol.%)     | 60.0                         |
| Carbon in cathode (vol.%)              | 5.0                          |
| Binder (PVDF) in cathode (vol.%)       | 5.0                          |
| Al foil thickness (μm)                 | 16.0                         |
| Separator thickness (μm)               | 16.0                         |
| Separator porosity (%)                 | 50.0                         |
| Al-plastic film thickness (μm)         | 150.0                        |
| Gr capacity (mAh g <sup>-1</sup> )     | 360.0                        |
| Gr potential (V vs. Li)                | 0.1                          |
| Anode porosity (vol.%)                 | 35.0                         |
| Active material in anode (vol.%)       | 62.0                         |
| Carbon in anode (vol.%)                | 0.6                          |
| Binder (CMC/SBR) in anode (vol.%)      | 2.4                          |
| Cu foil thickness (μm)                 | 8.0                          |
| N/P                                    | 1.05                         |
| Blade cell dimension (mm)              | 905 (L) × 118 (H) × 13.5 (D) |

Table S5. Cell parameters assumed in the analysis of ED of solid NCM523||Li.

| Speciation                                      | Values                       |
|---|------------------------------|
| NCM523 capacity (mAh g <sup>-1</sup> )          | 170.0                        |
| NCM523 potential (V vs. Li)                     | 3.7                          |
| Cathode thickness (μm)                          | 100.0                        |
| Electrolyte in cathode (vol.%)                  | 30.0                         |
| Active material in cathode (vol.%)              | 60.0                         |
| Carbon in cathode (vol.%)                       | 5.0                          |
| Binder in cathode (vol.%)                       | 5.0                          |
| Solid electrolyte separator thickness (μm)      | 100.0                        |
| Solid electrolyte separator porosity (vol.%)    | 0.0                          |
| Sulfidic solid electrolyte in separator (vol.%) | 95.0                         |
| Binder (NBR) in separator (vol.%)               | 5.0                          |
| Li capacity (mAh g <sup>-1</sup> )              | 3861.0                       |
| Li potential (V vs. Li)                         | 0.0                          |
| Anode porosity (vol.%)                          | 33.33                        |
| Active material in anode (vol.%)                | 66.66                        |
| Carbon in anode (vol.%)                         | 0.0                          |
| Binder in anode (vol.%)                         | 0.0                          |
| N/P   | 3.0                          |
| Bipolar CC thickness (μm)                       | 16 (8 μm Al + 8 μm Cu)       |
| Blade cell dimension (mm)                       | 905 (L) × 118 (H) × 13.5 (D) |

Notes: As the NCM523 contain lithium sources for lithium plating on the anode in the charge process, additional space is required for such amount of lithium. N/P = 3.0 means Twice amount of lithium is pre-stored in the negative sheet.

Table S6. Parameters intended to be tailored for progressively updating energy densities of SSBs.

| Variables                             | Values  |         |         |
|---------------------------------------|---------|---------|---------|
|                                       | Stage 1 | Stage 2 | Stage 3 |
| (i) Active materials                  | NCM811  | LM-NCM  | S       |
| g-ED (Wh kg <sup>-1</sup> )           | 322     | 372     | 505     |
| v-ED (Wh L <sup>-1</sup> )            | 711     | 741     | 603     |
| (ii) Content (vol.%)                  | 70      | 80      | 85      |
| g-ED (Wh kg <sup>-1</sup> )           | 293     | 321     | 333     |
| v-ED (Wh L <sup>-1</sup> )            | 683     | 751     | 783     |
| (iii) Cathode layer thickness (μm)    | 130     | 170     | 200     |
| g-ED (Wh kg <sup>-1</sup> )           | 292     | 319     | 333     |
| v-ED (Wh L <sup>-1</sup> )            | 672     | 731     | 763     |
| (iv) Solid electrolyte thickness (μm) | 70      | 50      | 20      |
| g-ED (Wh kg <sup>-1</sup> )           | 288     | 307     | 341     |
| v-ED (Wh L <sup>-1</sup> )            | 672     | 731     | 763     |
| (v) N/P                               | 2       | 1.5     | 1.05    |
| g-ED (Wh kg <sup>-1</sup> )           | 268     | 271     | 274     |
| v-ED (Wh L <sup>-1</sup> )            | 664     | 695     | 724     |
| (vi) Bipolar CC thickness (μm)        | 14      | 12      | 8       |
| g-ED (Wh kg <sup>-1</sup> )           | 270     | 278     | 294     |
| v-ED (Wh L <sup>-1</sup> )            | 614     | 618     | 627     |